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# IRAS 13568−6232: A QUIESCENT SYMBIOTIC MIRA?

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## ABSTRACT

The *IRAS* point source 13568−6232 has been suggested as a possible Vega-type system—i.e., a main-sequence A-type star with circumstellar dust emission—on the basis of its *IRAS* colors and LRS spectrum, and an apparent identification with the A2/5 V star HD 121918. We present broadband optical and near-infrared photometry, as well as positional measurements for HD 121918 and an alternative candidate star near the *IRAS* position. We deduce that the alternative (an anonymous red star) is the true optical counterpart of IRAS 13568−6232. An optical spectrum shows this object to be late M type. Its unusual near-infrared colors and 1–25 $\mu$m spectral energy distribution are similar to those of the slow symbiotic nova RR Tel.

*Subject headings:* binaries: symbiotic — circumstellar matter — infrared: stars — stars: individual (HD 121918, IRAS 13568−6232, RR Telescopii)

## 1. INTRODUCTION

IRAS 13568−6232 was proposed by Knacke et al. (1993) as a potential Vega-type system, i.e., a main-sequence star with infrared excess emission from circumstellar dust. This source is associated in the *IRAS* Point Source Catalog (Version 2, 1988, hereafter IPSC) with the star HD 121918, classified A2/5 (V) by Houk & Cowley (1975). It has a spectrum in the Atlas of Low Resolution *IRAS* Spectra (1988, hereafter LRS) displaying strong silicate emission similar to that of $\beta$ Pictoris, the well known Vega-type star (Knacke et al. 1993; Fajardo-Acosta & Knacke 1995). In this Letter, we examine the identity of the optical counterpart of IRAS 13568−6232, and we show that it is, in fact, associated with a faint anonymous star with strong near-infrared excess, and not with HD 121918. We attempt to establish the true nature of IRAS 13568−6232 by an investigation of its spectral characteristics and near-infrared and *IRAS* colors.

## 2. OBSERVATIONS AND RESULTS

The positional uncertainty of IRAS 13568−6232 is an error ellipse centered at R.A. = $13^h56^m51\overset{s}{.}8$, decl. = $-62°32'40''$; the semimajor and semiminor axes of the error ellipse are 18″ and 4″, respectively, and the position angle of the semimajor axis is 134° east of north (IPSC). The association of 13568−6232 with HD 121918 in the IPSC is therefore suspect, since this star lies ~32″ to the northwest of the *IRAS* position (see below), well outside the error ellipse. Examination of the region on sky survey plates indicates the existence of fainter candidates closer to the nominal *IRAS* position. A finding chart taken from the Digitized Sky Survey (UK Schmidt J plate) is shown in Figure 1, in which HD 121918 (star A) and the star we associate below with 13568−6232 (star B) are labeled.

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### 2.1. *HD 121918*

We obtained *UBVRI* and *JHK* photometry of HD 121918 with telescopes at the Sutherland site of the South African Astronomical Observatory (SAAO), as detailed below:

1.0 m telescope, St. Andrews photometer, 1994 May 7:

$$V = 10.23, \quad B - V = 0.27, \quad U - B = 0.16,$$

$$V - R_C = 0.15, \quad V - I_C = 0.30;$$

1.9 m telescope, Mk III infrared photometer, 1994 July 16:

$$K = 9.51, H - K = 0.01, J - H = 0.14.$$

Photometric errors are less than 0.02 mag at all passbands. The infrared measurements were made through a circular aperture 18″ in diameter, with a 30″ N-S chop for sky subtraction; results were reduced to the Carter (1990) photometric system.

Magnitudes were converted to fluxes using standard calibrations (Wilson et al. 1972; Bessell 1979), and the resulting spectral energy distribution is plotted in Figure 2 (*open circles*). This is compared with a simple model for an A2 V star, based on standard intrinsic colors (Johnson 1966; Bessell & Brett 1988; Caldwell et al. 1993) reddened to $E_{B-V} = 0.21$, using the mean interstellar extinction law (Whittet 1992, p. 67). We also tried other spectral types in the range A0 V–A5 V with similar results, although A2 gives the best fit. The generally good agreement between the data and this model indicates that, in terms of its optical and near-infrared photometric properties, HD 121918 behaves as a normal main-sequence star of spectral type around A2 and a modest degree of reddening. However, the lack of near-infrared excess emission does not exclude HD 121918 as a Vega-type star; the prototype itself has normal colors in the near-infrared.

### 2.2. *Star B*

We examined the region of the nominal *IRAS* position for alternative optical counterparts with the acquisition system on the 1.9 m telescope at SAAO (a red-sensitive CCD-based integrating TV camera). We found a faint star near the *IRAS* position, with exceptionally red colors in the near-infrared (see below), which we identify as object B in Figure 1. Its position

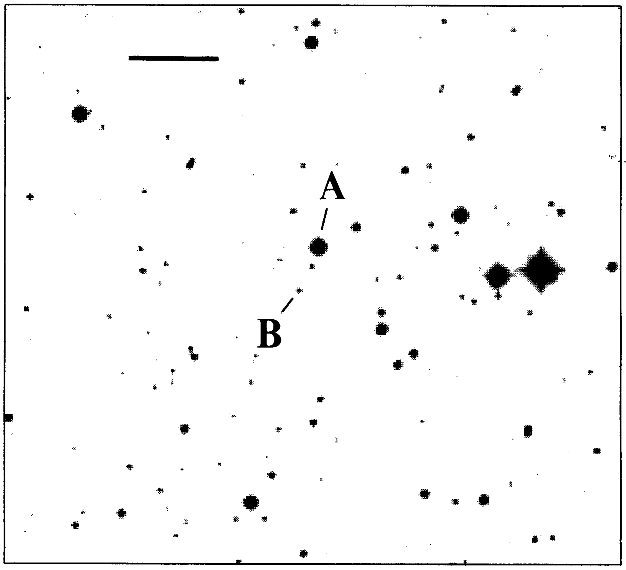


FIG. 1.—A Digitized Sky Survey image from the UK Schmidt J plate centered on the position of IRAS 13568−6232. North is up and east is to the left. The scale bar at upper left is 1′. Star A is HD 121918 and star B is the star we associate with IRAS 13568−6232. The bright star at center right is HD 121857.

and that of HD 121918 were determined from the 1.9 m telescope pointing relative to nearby bright stars. Results (equinox 1950) are accurate to ±5″, and they are compared below with the nominal catalog position of the *IRAS* source from the IPSC:

| | | |
|---|---|---|
| HD 121918: | R.A. = $13^h56^m50\overset{s}{.}5$, | decl. = −62°32′08″ |
| 13568−6232: | R.A. = $13^h56^m51\overset{s}{.}8$, | decl. = −62°32′40″ |
| Star B: | R.A. = $13^h56^m52\overset{s}{.}0$, | decl. = −62°32′38″ |

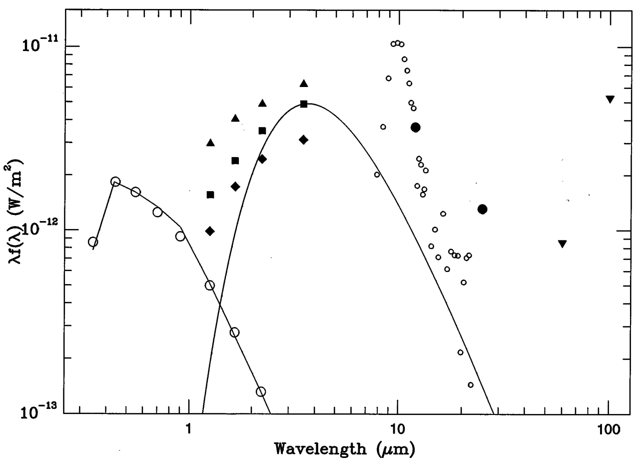


FIG. 2.—Spectral energy distributions of HD 121918 = star A (*large open circles*) and IRAS 13568−6232 = star B (*all other symbols*). Data for HD 121918 are fitted with a model based on intrinsic colors for an A2 V star with reddening $E_{B-V}$ = 0.21, normalized to $V$ = 10.23. Representative ground-based near-infrared photometry for star B (Table 1) are plotted as upright triangles (1994 July data; mean of two measurements), diamonds (1995 April data; mean of two measurements), and squares (1995 August 8 data). *IRAS* photometry from the IPSC are plotted as filled circles (12 and 25 μm data without color correction) and inverted triangles (60 and 100 μm limiting values). *IRAS* LRS data (*small open circles*) are scaled to match the broadband data at 12 μm. Also shown for comparison is a $T$ = 1000 K blackbody curve scaled to the median 3.5 μm observation of star B.

TABLE 1

INFRARED PHOTOMETRY OF IRAS 13568−6232 OBSERVED WITH THE SAAO 1.9 m TELESCOPE

| JD − 2,440,000 | $J-H$ | $H-K$ | $K$ | $K-L$ | Aperture |
|---|---|---|---|---|---|
| 9550.25 | 1.11 | 1.02 | 5.59 | 1.63 | 18″ |
| 9553.25 | 1.11 | 1.02 | 5.57 | 1.67 | 18 |
| 9825.62 | 1.41 | 1.18 | 6.35 | 1.59 | 12 |
| 9831.56 | 1.37 | 1.22 | 6.32 | 1.64 | 12 |
| 9938.22 | 1.24 | 1.23 | 5.95 | 1.72 | 12 |
| 9961.20 | 1.23 | 1.24 | 5.58 | 1.65 | 12 |
| 10096.60 | 1.14 | 1.13 | 5.76 | 1.82 | 18 |

The nominal 1950 position of HD 121918 is R.A. $13^h56\overset{m}{.}9$, decl. −62°32′ (SIMBAD database), in good agreement with our measurement of its position. IRAS 13568−6232 and star B are clearly coincident to within measurement errors.

We obtained near-infrared photometry of star B with the 1.9 m telescope and Mk III infrared photometer at SAAO on a total of seven occasions, between 1994 July 16 and 1996 January 13. Results are listed in Table 1. In each case, the chop amplitude was 30″ N-S. Photometric errors are less than 0.02 at *JHK* and less than 0.04 at $L$. These data show that (1) the star exhibits substantial variability on a timescale ∼0.5 yr, and (2) its colors are very red, particularly in $H-K$ and $K-L$, compared with normal late-type stars or highly reddened objects (e.g., Bessell & Brett 1988).

Spectral energy distributions deduced from our *JHKL* photometry of star B and *IRAS* (LRS, IPSC) data for IRAS 13568−6232 are compared with that of HD 121918 in Figure 2. *JHKL* measurements separated by a few days (Table 1) have been averaged to give representative sets of photometry. The 60 and 100 μm fluxes are limiting values because of confusion with background radiation from the Galactic plane (the Galactic latitude of 13568−6232 is only $-0\overset{\circ}{.}96$). The luminosity of a blackbody in the $\lambda f(\lambda)$ plot of spectral energy distribution is proportional to $[\lambda f(\lambda)]_{max}$ (see Appendix A of Gehrz & Ney 1992). A reasonable lower limit to the total infrared flux from 13568−6232 is provided by the 1000 K blackbody shown in Figure 2. Comparing this with the spectral energy distribution of HD 121918, it is apparent that the infrared source is more luminous than the star by a factor of at least ∼2 if they are at the same distance. Given its low reddening, it is therefore highly implausible that HD 121918 could be the energy source driving the infrared emission.

On the basis of both positional measurements and energy considerations, we rule out an association between IRAS 13568−6232 and HD 121918. We identify star B as the true optical counterpart of the *IRAS* source, and turn our attention to determining its nature.

We obtained an optical spectrum of star B on 1994 September 29 with the image-tube spectrograph and Reticon photon-counting system on the 1.9 m telescope at SAAO. Grating 7 was used to give a dispersion of 210 Å $mm^{-1}$ (∼8 Å resolution). The effective spectral range covered was about 3500–7000 Å, although very little flux was detected from this object blueward of about Hβ in 2 × 1200 s of integration. Although the signal-to-noise ratio is low, the spectrum clearly shows molecular absorption bands characteristic of a mid to late M-type giant star, and we assign a tentative spectral type of M6–8 III. This classification is consistent with some of the photometric properties of 13568−6232. The *IRAS* color [12] − [25] = 1.01 (Cheeseman et al. 1989) is within the expected range for late M-type red giants with dust shells. If we allow for some foreground reddening, the $J - H$ color of the star (Table 1) is also compatible with the spectral type, but the $H - K$ and $K - L$ colors are clearly anomalous.[4]

The LRS spectrum of IRAS 13568−6232 (see Fig. 2) is totally dominated by emission in the 9.7 $\mu$m silicate stretching mode. Both the continuum and the silicate bending mode at 18 $\mu$m are relatively weak. The LRS spectral class is 29 (strongest silicate emission), and the LRS autoclass (Cheeseman et al. 1989) is $\beta$7. Sources with identical or similar LRS classes tend to be distributed within $\sim$20° of the Galactic plane and preferentially toward the Galactic center (Fajardo-Acosta & Knacke 1995), and many of them (including 13568−6232) are noted as probably variable in the IPSC. The majority of stars with known optical associations in these classes are Mira variables or red supergiants (Fajardo-Acosta & Knacke 1995). On the basis of its optical and LRS spectral classifications and its photometric variability, we conclude that 13568−6232 is most likely a Mira.

## 3. A SYMBIOTIC NOVA SYSTEM?

The results presented in the previous section indicate that the only available observations that distinguish IRAS 13568−6232 from a normal Mira are the remarkable excesses in the $H - K$ and $K - L$ colors. These colors suggest the presence of dust at temperatures $\sim$1000–1500 K, much hotter than are found in normal Mira envelopes.

Strong infrared excess in the $H - K$ and $K - L$ colors is somewhat characteristic of the symbiotic stars (e.g., $\sim$20% of the symbiotics listed by Munari et al. 1992 show this phenomenon). The slow symbiotic nova RR Tel, in particular, displays near-infrared colors similar to those of IRAS 13568−6232 (Feast et al. 1983; Munari et al. 1992; Whitelock et al. 1994). The RR Tel system is thought to contain a Mira primary and a hot white dwarf secondary. The primary is undergoing rapid mass loss and its colors are being modified both by reddening and by emission from circumstellar dust (e.g., Kenyon & Truran 1983; Schild 1989; Munari et al. 1992; Whitelock et al. 1994). Excess heating of the circumstellar dust is attributed to the strong contribution of the white dwarf to the short-wavelength radiation field (Whitelock 1987), resulting in a distinctive spectral energy distribution. The spectral energy distribution of RR Tel (Bryan & Kwok 1991; see their Fig. 2*c*) shows considerable resemblance to that for IRAS 13568−6232 (Fig. 2) in the near- to mid-infrared. Another resemblance is that RR Tel has silicate emission; the LRS class is 26, indicating moderately strong silicate emission (see also Bryan & Kwok 1991).

An important difference between the two objects is that RR Tel exhibits an extreme emission-line spectrum (Thackeray 1977; Penston et al. 1983), whereas no emission lines are apparent in our spectrum of IRAS 13568−6232. A possibility is that 13568−6232 is currently in a quiescent state, perhaps similar to RR Tel prior to its 1944 outburst, in which ionizing radiation from the white dwarf is being strongly absorbed by circumstellar dust.

## 4. CONCLUSIONS

We have shown that IRAS 13568−6232 is identified with a faint M6–8 III star. Its previous association with the main-sequence A star HD 121918 is shown to be spurious. Both the M star and the *IRAS* source have properties of an oxygen-rich red giant, most probably a Mira, but with circumstellar dust hotter than can be explained by heating due to radiation from the red giant alone. A comparison with RR Tel suggests that 13568−6232 might be a symbiotic binary, with a hot white dwarf secondary as the source of excess heating of dust in a common envelope. If so, the lack of an emission-line spectrum appears to indicate that ionizing radiation from the white dwarf is being veiled by the dust.

Future long-term photometric and spectroscopic monitoring of IRAS 13568−6232 could prove interesting. One aim would be to provide confirmation of Mira-like variability. The possibility also exists of nova outbursts from the source in the future.

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[4] Bessell & Brett (1988) list intrinsic colors $(J - H)_0 = 0.96$ and $(H - K)_0 = 0.31$ for an unreddened star of spectral type M7 III, and, by extrapolation, we deduce $(K - L)_0 \approx 0.20$.

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